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OPTICAL PROPERTIES OF THE ATMOSPHERE OF PLANET MARS IN THE ULTRAVIOLET SPECTRUM REGION

by

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OPTICAL PROPERTIES OF THE ATMOSPHERE OF PLANET MARS IN THE ULTRAVIOLET SPECTRUM REGION *

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SUMMARY

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It is shown that during the 1956 opposition, the optical thickness of the atmosphere of Mars in the spectral region $\tilde{\lambda} = 360\,m\mu$ was considerably greater than the unity. It is assumed that the "ultraviolet layer" of the atmosphere of Mars consists of a mixture of gas with aerosol particles. It was found, that at this mixture's single scattering, the albedo of particles is 0.50.

Using the Rocard theory for the interpretation of atmosphere indicatrices, the scattering indicatrix was obtained in the indicated spectral region and the mean radius of the aerosol particle was found to be $0.9 \cdot 10^{-5}$ cm. It was found that aerosol particles have an albedo of single scattering equal to 0.38 and that the concentration of these particles in the "ultraviolet layer" is rather high.

Author

* * *

An attempt is made in this work to determine the properties of the atmosphere of Mars in the ultraviolet ($\tilde{\lambda} = 360\,m\mu$), starting from the results of observations obtained by Barabashov and Koval' [1] during the 1956 opposition.

To that effect, we took advantage of the formulas expressing the coefficient of brightness of the atmosphere for the case, when

* Ob opticheskikh svoystvakh atmosfery Marsa v ul'trafioletovom uchastke spektra.

when the latter's optical thickness $\tau_0 = \infty$. The possibility of utilizing formulas of that form stems from the facts expounded below.

As follows from the tables of the catalogue in ref. [1], and also from the analysis conducted in [2] for the period from 4 to 15 September 1956, which is precisely the one we shall consider here, the brightness distribution along the disk of Mars in the ultraviolet remained constant, i. e. the foggy mist observed at that time in the atmosphere of Mars with other filters ($\tilde{\lambda} \geqslant 530\,m\mu$), did not affect the distribution of brightness in the ultraviolet. Apparently, the particles suspended in the atmosphere and having formed that mist, did not rise above the ultraviolet layer.

Therefore, the parameters, which will be found here, evidently will represent the optical properties of this layer.

Besides, the validity of such admission is still corroborated by the fact that " dark details in planet's disk were only very seldom seen as weak, hardly distinguishable shadows, when looking through an ultraviolet light filter", as this was noted in reference [1].

The above-mentioned arguments can be only valid in the case, when the true contrast "continent-mare" remained sufficiently great in the indicated spectrum region.

This fact finds a certain confirmation in the work by Barabashov and Koval' [3], in which it is shown that, apparently, the true contrast "continent-mare" remained nearly identical in the red as well as in a blue filter.

These qualitative reasonings will be corroborated by a quantitative estimate.

Let us draw attention to the fact, that a light (clear) formation, noted by Barabashov on 23 August 1956, in the region Argyr I, was well visible through the red and green filters and completely invisible in the ultraviolet one [1]. If we assume that this formation is related to frost-like deposits on Mars' surface (in the opposite case it would be difficult to explain the long preservation of such formation), and

take into account that its brightness was approximately the same as that of the polar cap for $\tilde{\lambda} = 650\,m\mu$ [1], we may approximately postulate that the albedo of this formation $A \approx 0.5$ [4]. According to E. L. Krivov, [5], for snow the albedo is $A(\tilde{\lambda}) \approx$ const. N. N. Sytinskaya [6] obtained for the ultraviolet filter ($\tilde{\lambda} = 380\,m\mu$) the value of the albedo of the Mars' "continent" equal to $A_C = 0.064$.

Let us estimate for what value of τ_0 the clear formation, having $A = 0.5$, will cease to be distinguishable against a background with $A_C = 0.1$ (we take a somewhat overrated value), i. e. when the contrast reaches the threshold contrast sensitivity of vision. For the latter quantity we shall take the value of 5 percent (5%) [7].

We shall make use of approximate formulas by Sobolev [8] for the coefficient of brightness obtained in the case of pure scattering. The first coefficient x_1 in the expansion of the scattering indicatrix by Legendre polynomials will be assumed equal to the unity ($x_1 = 1$). As is shown by the computation for the center of the disk in case of true opposition, the above-indicated value of optical thickness is found to be equal to $\tau_0 \approx 9$. If, moreover, we take into account that the atmosphere of Mars in the indicated spectrum region is endowed with a significant true absorption (as will be shown below), the latter quantity would have to be somewhat increased.

Therefore, we reach the conclusion, that if we consider the above assumptions as valid, the optical thickness of the atmosphere of Mars for the wavelength $\tilde{\lambda} = 360\,m$ was substantially greater than the unity during the 1956 opposition.

As already mentioned above, we shall take advantage of the approximate formula for the coefficient of brightness at $\tau_0 = \infty$ [9, 10].

$$\rho(\eta, \zeta, \alpha) = \rho_1^{*}(\eta, \zeta, \alpha) + \frac{\lambda}{4}\,\frac{\chi(\gamma)}{\eta + \zeta}, \qquad (1)$$

where η is the cosine of the incidence angle, ζ is the cosine of the angle of light reflection, α is the phase angle of the planet. The scatterring of the first order is taken into account in formula (1) in a precise

fashion (the second addend of the right-hand part), and $\rho^{*}(\eta, \zeta, \alpha)$ is the brightness coefficient of the diffusively-reflected radiation, conditioned by scatterings of higher orders. It was shown in the works [9, 10] that

$$\rho^{*}(\eta, \zeta, \alpha) = \frac{\lambda}{4}\,\frac{1}{\eta+\zeta}\{\varphi_0^{\circ}(\eta)\varphi_0^{\circ}(\zeta) - 1 - x_1[\varphi_1^{\circ}(\eta)\varphi_1^{\circ}(\zeta) - \eta\zeta - (1-\varphi_1(\eta)\varphi_1(\zeta))(\cos\alpha - \eta\zeta)]\}, \tag{2}$$

where

$$\varphi_0^{\circ}(\eta) = \frac{[(1-\lambda)(2-\lambda x_1\eta)+k](1+2\eta)}{[2(1-\lambda)+k](1+k\eta)}, \tag{3}$$

$$\varphi_1^{\circ}(\eta) = \frac{(1-\lambda)(2+k)(1+2\eta)\eta}{[2(1-\lambda)+k](1+k\eta)}, \tag{4}$$

$$\varphi_1(\eta) = \frac{1+2\eta}{1+k_1\eta}, \tag{5}$$

$$k^2 = (1-\lambda)(4-\lambda x_1), \tag{6}$$

$$k_1^2 = 4 - {}^3/_2\lambda x_1, \tag{7}$$

λ being the ratio of the coefficient of scattering to the sum of the coefficients of scattering and of true absorption, or the probability of quantum survival at single scattering, γ is the scattering angle.

In deriving formula (2) we took advantage of the V. V. Sobolev idea [11, 12], by representing for scatterings of higher orders the scattering indicatrix in the form

$$\chi(\gamma) = 1 + x_1\cos\gamma, \tag{8}$$

where

$$x_1 = \frac{3}{2}\int_0^{\pi}\chi(\gamma)\sin\gamma\cos\gamma\,d\gamma. \tag{9}$$

Formula (1) is analogous to the formula obtained by V. V. Sobolev [12], but more convenient for calculations.

Now the problem consists in determining the optical parameters and x_1, knowing the distribution of brightness along the disk of Mars in the considered spectrum portion [1] and utilizing formula (1).

To that effect we computed the Tables 1 through 6, using the formula (2). In these tables we compiled the values of ρ^* at $\alpha = 0$ ($\eta = \zeta$) and for various values of λ and x_1. They may be also utilized for an approximated determination of the atmosphere parameters of Jupiter and Saturn.

In order of find λ and x_1, we must yet assign a form to the scattering indicatrix $\chi(\gamma)$, which obviously depends on the physical nature of the particles forming the ultraviolet layer.

There are two points of view on the nature of ultraviolet absorption in the atmosphere of Mars (see for example [13]); the molecular absorption and the absorption on aerosol particles. Inasmuch as the first viewpoint has not, heretofore, obtained a reliable corroboration [14], we shall adopt the second one.

At the outset, we shall assume, for the sake of simplicity, that the ultraviolet layer consists only of aerosol, forming particles of spherical shape. The theory of scattering on particles of spherical shape is sufficiently well developed (see for example [15, 16]).

We shall make use of one of the variants of the approximate theory of light scattering on particles of spherical shape, whose electric properties differ little from those of the surrounding medium. This theory was proposed by Rocard [17] and improved in the paper by K. S. Shifrin and V. F. Raskin [18].

In the Rocard theory the averaging of the scattering indicatrix of the atmosphere is conducted for the particles'distribution function by dimensions of the form

$$\Phi(a)\,da = \frac{27}{2} e^{-3(a/\bar{a})} \left(\frac{a}{\bar{a}}\right)^2 d\left(\frac{a}{\bar{a}}\right). \qquad (10)$$

Here $\Phi(a)\,da$ is the fraction of particles, whose radii are included within the limits a to a + da, $\bar{a}$ is the mean radius of particles. The following formula is brought out in [18] for the scattering indicatrix

$$\chi(\gamma, \nu) = \frac{3}{4}(1 + \cos^2\gamma)\frac{\varphi(u)}{\psi(\nu)}, \qquad (11)$$

where

$$u = \nu \sin \frac{\gamma}{2}, \qquad (12)$$

$$\nu = \frac{4}{3} \frac{2\pi \bar{a}}{\tilde{\lambda}}, \qquad (13)$$

and the functions $\varphi(u)$ and $\psi(\nu)$ are tabulated.

Substituting formula (9) into (11) after taking into account the expression for the function $\varphi(u)$, brought out in [18], we shall find upon integration :

$$x_1(\nu) = 3 - \frac{32(3\nu^2 - 2)}{9\psi(\nu)\nu^6} \ln(1 + \nu^2) - \frac{16(7\nu^8 + 22\nu^6 + 43\nu^4 + 8\nu^2 + 4)}{9\psi(\nu)\nu^4(1 + \nu^2)^4}. \qquad (14)$$

The values of $x_1(\nu)$ for various ν are compiled in Table 7.

In computing the formula (14), it is useful to bear in mind the following asymptotic formulas

For $\nu \gg 1$

$$x_1(\nu) = 3 - \frac{8}{5} \frac{\ln \nu}{\nu^2} - \frac{14}{15} \frac{1}{\nu^2} + \ldots, \qquad (15)$$

For $\nu \ll 1$

$$x_1(\nu) = \frac{27}{10} \nu^2 - \frac{2601}{1400} \nu^4 + \ldots. \qquad (16)$$

The values of $\rho(\eta)$, found with the aid of the catalogue of [1], near the opposition, are compiled in line 2 of Table 8. Utilizing these values of the coefficient of brightness, we obtain with the aid of Tables 1 — 6, of formulas (1) and (11), and taking into account the tables of functions $\varphi(u)$ and $\psi(\nu)$, brought out in [18], that $\lambda = 0.54$, $x_1 = 1.26$. The values of the coefficient of brightness, computed for the found values of λ and x_1, are compiled in the third line of Table 8.

Therefore, we reach the conclusion that the atmosphere of Mars is endowed for $\tilde{\lambda} = 360\,m\mu$ with a strongly extended scattering indicatrix ($x_1 = 1.26$). Besides, the atmosphere is strongly absorbent (the albedo of the single scattering being $\lambda = 0.54$). Consequently, when computing the second addend of the right-hand part of formula (1), we should take into account that a certain part of light will be diffusively reflected directly by the gas component of the atmosphere, where aerosol particles are suspended.

Table 1

$\rho^*(1.0)\cdot 10^3$										
x_1 \ λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
0.0	3.93	9.72	19.2	34.0	56.6	91.8	151	267	393	1000
0.2	3.91	9.69	19.2	34.1	56.8	92.6	153	272	399	1025
0.4	3.81	9.50	18.9	33.7	56.5	92.5	153	275	408	1050
0.6	3.65	9.15	18.3	32.9	55.5	91.5	153	277	413	1075
0.8	3.42	8.64	17.5	31.5	53.7	89.5	151	278	417	1100
1.0	3.12	7.95	16.2	29.7	51.2	86.4	148	277	419	1125
1.1	2.94	7.54	15.5	28.6	49.6	84.4	146	275	420	1137
1.2	2.74	7.09	14.7	27.3	47.8	82.1	143	274	420	1150
1.3	2.52	6.59	13.8	25.9	45.8	79.5	140	271	420	1162
1.4	2.28	6.04	12.8	24.3	43.6	76.6	137	268	416	1175
1.5	2.02	5.45	11.7	22.6	41.1	73.3	133	265	414	1187
1.6	1.75	4.80	10.5	20.7	38.3	69.6	129	260	413	1200
1.7	1.45	4.11	9.27	18.6	35.3	65.5	123	255	410	1212
1.8	1.13	3.36	7.89	16.4	32.0	60.9	118	250	407	1225
1.9	0.796	2.57	6.41	14.0	28.4	56.0	112	243	406	1237
2.0	0.437	1.72	4.83	11.4	24.6	50.6	105	235	401	1250

Table 2

$\rho^*(0.9)\cdot 10^3$										
x_1 \ λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
0.0	4.19	10.4	20.4	36.0	59.5	96.0	156	273	394	950
0.2	4.16	10.3	20.4	36.0	59.7	96.7	158	277	401	972
0.4	4.05	10.1	20.1	35.5	59.2	96.3	158	280	409	994
0.6	3.86	9.65	19.8	34.4	57.8	94.8	157	281	410	1015
0.8	3.59	9.03	18.2	32.8	55.6	92.1	154	279	412	1035
1.0	3.22	8.21	16.7	30.5	52.4	88.0	150	276	412	1054
1.1	3.01	7.72	15.8	29.1	50.4	85.4	147	273	410	1063
1.2	2.77	7.17	14.9	27.5	48.1	82.4	143	270	408	1071
1.3	2.51	6.57	13.8	25.8	45.6	79.0	139	266	405	1079
1.4	2.23	5.91	12.6	23.8	42.8	75.1	134	261	401	1087
1.5	1.92	5.20	11.2	21.7	39.6	70.7	128	255	396	1094
1.6	1.59	4.42	9.80	19.4	36.1	65.9	122	247	390	1100
1.7	1.24	3.59	8.24	16.8	32.3	60.5	115	239	382	1105
1.8	0.861	2.69	6.55	14.0	28.1	54.5	107	230	374	1109
1.9	0.458	1.73	4.74	11.0	23.5	47.8	98.0	218	363	1112
2.0	0.029	0.70	2.79	7.78	18.4	40.5	87.9	206	349	1113

Table 3

$\rho^*(0.8)\cdot 10^3$										
x_1 \ λ	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
0.0	4.49	11.1	21.8	38.1	62.8	101	162	279	396	900
0.2	4.46	11.0	21.7	38.1	62.9	101	163	282	403	919
0.4	4.33	10.7	21.2	37.4	62.2	100	163	284	407	938
0.6	4.10	10.2	20.4	36.2	60.4	98.4	161	283	407	954
0.8	3.78	9.49	19.1	34.2	57.7	94.9	157	281	408	969
1.0	3.36	8.52	17.3	31.4	53.7	89.7	151	275	405	982
1.1	3.10	7.94	16.3	29.8	51.3	86.4	147	271	402	987
1.2	2.83	7.30	15.1	27.9	48.6	82.7	143	265	395	992
1.3	2.52	6.59	13.8	25.8	45.5	78.4	137	259	387	996
1.4	2.19	5.81	12.3	23.4	42.0	73.6	131	252	386	998
1.5	1.83	4.97	10.8	20.9	38.1	68.2	124	244	377	1000
1.6	1.44	4.05	9.06	18.1	33.9	62.1	116	234	366	1000
1.7	1.03	3.06	7.20	15.0	29.2	55.3	106	222	353	998
1.8	0.585	2.00	5.19	11.6	24.0	47.8	95.9	209	342	994
1.9	0.112	0.866	3.03	7.99	18.4	39.5	84.2	193	324	988
2.0	0.000	0.000	0.701	4.05	12.2	30.3	71.1	175	307	978

Table 4

λ / x_1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
				$\rho^{*}(0.7)\cdot 10^{3}$						
0.0	4.84	11.9	23.3	40.6	66.5	106	168	284	398	850
0.2	4.80	11.8	23.2	40.5	66.5	106	169	287	402	867
0.4	4.65	11.5	22.6	39.7	65.5	105	169	288	404	881
0.6	4.39	10.9	21.6	38.1	63.3	102	166	286	406	894
0.8	4.01	10.0	20.1	35.8	60.0	97.9	161	281	404	904
1.0	3.52	8.90	18.0	32.5	55.3	91.6	153	273	397	910
1.1	3.23	8.22	16.8	30.5	52.4	87.6	148	267	393	912
1.2	2.90	7.47	15.4	28.3	49.1	83.1	142	260	384	913
1.3	2.55	6.65	13.9	25.8	45.4	77.9	135	252	377	912
1.4	2.17	5.74	12.2	23.1	41.3	72.1	127	243	368	910
1.5	1.75	4.76	10.3	20.1	36.7	65.5	118	232	356	906
1.6	1.30	3.69	8.34	16.7	31.6	58.2	108	219	342	900
1.7	0.819	2.54	6.16	13.1	26.0	50.1	97.1	205	327	891
1.8	0.304	1.31	3.81	9.17	19.9	41.0	84.4	187	306	879
1.9	0000	000	1.27	4.87	13.2	31.0	70.0	167	286	864
2.0	0000	000	000	0.226	5.80	19.9	53.8	144	260	844

Table 5

λ / x_1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
				$\rho^{*}(0.6)\cdot 10^{3}$						
0.0	5.25	12.8	25.0	43.4	70.5	111	175	289	398	800
0.2	5.20	12.7	24.8	43.2	70.4	111	176	292	401	814
0.4	5.02	12.3	24.2	42.2	69.1	110	174	291	403	825
0.6	4.72	11.7	23.0	40.4	66.5	106	170	288	402	833
0.8	4.28	10.7	21.2	37.6	62.6	101	164	281	396	838
1.0	3.72	9.36	18.8	33.8	57.0	93.6	154	270	388	838
1.1	3.38	8.57	17.4	31.5	53.6	88.9	148	263	379	837
1.2	3.01	7.71	15.8	28.9	49.8	83.5	141	254	368	833
1.3	2.60	6.75	14.0	26.0	45.4	77.4	133	244	359	828
1.4	2.16	5.71	12.1	22.8	40.6	70.5	123	232	350	821
1.5	1.68	4.57	9.95	19.3	35.2	62.7	113	218	331	812
1.6	1.16	3.35	7.63	15.4	29.3	54.1	101	203	314	800
1.7	0.608	2.02	5.11	11.2	22.8	44.5	87.4	185	297	784
1.8	0.015	0.589	2.38	6.63	15.6	33.9	72.2	164	273	765
1.9	000	000	000	1.65	7.76	22.1	55.2	140	245	742
2.0	000	000	000	000	000	9.13	36.0	112	213	712

Table 6

λ / x_1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95	1.0
				$\rho^{*}(0.5)\cdot 10^{3}$						
0.0	5.73	13.9	27.0	46.6	75.1	117	182	294	399	750
0.2	5.67	13.8	26.8	46.3	74.9	117	182	296	401	761
0.4	5.46	13.4	26.0	45.1	73.3	115	180	295	400	769
0.6	5.11	12.6	24.6	42.9	70.2	111	175	290	397	773
0.8	4.61	11.4	22.6	39.7	65.5	105	167	280	388	772
1.0	3.96	9.91	19.8	35.3	59.0	95.7	155	266	375	766
1.1	3.57	9.01	18.2	32.6	55.0	90.2	148	257	365	761
1.2	3.15	8.02	16.3	29.6	50.5	83.8	140	247	353	753
1.3	2.68	6.92	14.3	26.3	45.5	76.7	130	234	340	744
1.4	2.17	5.72	12.0	22.6	39.9	68.7	119	220	324	732
1.5	1.62	4.42	9.58	18.5	33.7	59.7	107	204	304	717
1.6	1.03	3.00	6.92	14.1	26.9	49.7	92.6	185	284	700
1.7	0.396	1.48	4.03	9.25	19.4	38.7	77.0	164	262	678
1.8	0.000	1.53	0.904	3.98	11.1	26.4	59.4	139	235	652
1.9	0.000	0.00	0.000	0.00	2.11	12.9	39.7	111	201	621
2.0	0.000	0.00	0.000	0.00	0.771	2.06	17.7	79.5	165	583

TABLE 7

$x_1(v)$	0.00	0.2	0.4	0.6	0.8	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7
v	0.00	0.28	0.40	0.51	0.61	0.71	0.76	0.81	0.86	0.92	0.98	1.04	1.11
$x_1(v)$	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0
v	1.19	1.28	1.37	1.48	1.62	1.78	1.97	2.24	2.67	3.3	4.0	6.3	∞

TABLE 8

η	1.0	0.9	0.8	0.7	0.6	0.5
p	0.061	0.064	0.069	0.074	0.082	0.094
ρ	0.063	0.066	0.068	0.075	0.082	0.092

We shall denote by n the probability that light will be scattered by particles in an elementary volume of the mixture of gas with aerosol particles. Consequently, the quantity n will characterize the concentration of aerosol particles. Then, the scatteringindicatrix for the indicated mixture will be

$$\chi(\gamma) = \frac{(1-n)\chi_R(\gamma) + \lambda_a n \chi_a(\gamma)}{1 - n + \lambda_a n}, \qquad (17)$$

where

$$\chi_R(\gamma) = \frac{3}{4}(1 + \cos^2\gamma), \qquad (18)$$

λ_a being the albedo of the single scattering on an aerosol particle, $\chi_a(\gamma)$ is the scattering indicatrix on aerosol particles.

The quantity

$$\lambda = 1 - n(1 - \lambda_a), \qquad (19)$$

evidently represents the probability of quantum survival at scattering on the mixture gas + aerosol particles. Besides, from (17) we find

$$x_1 = \frac{\lambda_a n x_{1a}}{1 - n(1 - \lambda_a)}, \qquad (20)$$

where

$$x_{1a} = \frac{3}{2}\int_0^\pi \chi_a(\gamma)\sin\gamma\cos\gamma\, d\gamma. \qquad (21)$$

Taking into account that in our case $\alpha \approx 0$, we find from (1)

$$\rho(\eta) - \rho^*(\eta) = \frac{\lambda}{8\eta}\chi(\pi), \qquad (22)$$

whence

$$\frac{\rho(\eta) - \rho^*(\eta)}{\rho(1) - \rho^*(1)} = \frac{1}{\eta}. \qquad (23)$$

As in the preceding case, using Tables 1 — 6, for the distribution of brightness, given by the first line of Table 8, we find λ and x_1 from the equations (23) and then, from the equation (22) we obtain the value of $\chi(\pi)$. As a result, we find $\lambda = 0.50$, $x_1 = 1.50$, $\chi(\pi) = 0.61$. This result is obtained without any sort of assumptions relative to the form of the indicatrix $\chi(\gamma)$.

Assume now that the scattering indicatrix on aerosol particles $\chi(\gamma)$ is determined by formula (11). Then, from formulas (11), (12) and (17), we have

$$\lambda\chi(\pi) = \frac{3}{2}\left[1 - n + \lambda_a n \frac{\varphi(\nu)}{\psi(\lambda)}\right]. \qquad (24)$$

Resolving the system of equations (19), (20) and (24), relative to λ_a, x_{1a} and n, we obtain $\lambda_a = 0{,}38$; $x_{1a} = 2.46$; $\nu = 2.1$; $n = 0.81$. At the same time we took advantage of Table 7 and of tables for the functions $\varphi(u)$ and $\psi(v)$, brought out in [18].

Starting from the formula (13), we find the mean dimension of aerosol particles $\bar{a} = 0.9 \cdot 10^{-5}$ cm forming the ultraviolet layer. Note that the Rocard theory was utilized by I. N. Minin [19] for the estimate of particle dimensions in dust nebulae.

We also draw the attention to the fact that Schatzman [20] interpreted the optical properties of the ultraviolet layer mainly by starting from the assumption that the latter consists of spherical water droplets with radii $a = 1.5 \cdot 10^{-5}$ cm. However, Schatzman himself feels that this assumption is still insufficiently founded and he gives preference to the theory, according to which the ultraviolet layer is much rather formed by dust particles or tiny crystals.

Therefore, we reached the following results :

1. - During the great 1956 opposition, the optical thickness of Mars in the region $\tilde{\lambda} = 360$ mμ was substantially greater than the unity.

2.- Starting from the assumptions that the ultraviolet layer is costituted of a mixture gas + aerosol particles, we obtain that the single scattering albedo of this mixture is $\tilde{\lambda} = 0.5$. It should be noted

here, that according to data by Sytinskaya [6], for $\tilde{\lambda} = 380$ mμ, it was obtained [21], that $\lambda = 0.54$ and $\tau_0 = 0.70$. Therefore, the atmosphere of Mars may be endowed for the region $\lambda < 400$ mμ with a significant true absorption.

3.- The scattering indicatrix of the atmosphere for the wavelength region near $\tilde{\lambda} = 360$ mμ is considerably stretched forward ($x_1 = 1.5$).

4.- The concentration of aerosol particles in the ultraviolet layer is rather high ($n = 0.86$).

5.- The aerosol particles are endowed with a strong true absorption; the albedo of single scattering is for them $\lambda_a = 0.38$.

6.- The mean dimension of aerosol particles is $\bar{a} = 0.9 \cdot 10^{-5}$cm.

Knowing $\bar{a}$, λ_a and n, we may obtain through formulas (17) and (11) the mean scattering indicatrix in the atmosphere of Mars. This indicatrix is compiled in the second line of Table 9. The third line of this Table gives the Rocard scattering indicatrix for $\nu = 2.1$.

TABLE 9

γ	0°	10	20	30	40	50	60	70	80	90	120	150	180°
χ	10.8	9.3	6.1	3.4	1.8	1.0	0.65	0.49	0.38	0.34	0.38	0.52	0.61
χ_a	16.6	14.2	9.1	4.7	2.2	0.99	0.48	0.26	0.14	0.10	0.05	0.04	0.04

It should be noted that the above-presented results of calculations have quite an approximate character. Firstly, formula (1) is approximate, and since the scattering indicatrix for the ultraviolet layer of the atmosphere of Mars was found to be strongly elongated forward, a greater number of terms in the expansion of the scattering indicatrix by Legendre polynomials should be taken into account for scatterings of higher orders. However, such generalization is beset with great difficulties of calculatory character. Secondly, formula (11) also is approximate and valid for particles of not too great a radius [18]. Thirdly, the distribution function of particles by dimensions can strongly differ from the function diven by formula (10). Finally, among particles forming

the ultraviolet layer, a specific number of particles can be found, whose electric properties differ considerably from those of the surrounding medium. To this, in particular, points the fact that, as was shown above, the albedo of aerosol particles was found to be quite low.

Consequently, for reliable conclusions as regards the physical properties of the atmosphere of Mars in the ultraviolet, the shortcomings of the theory, applied here, should be taken into account.

Let us stress in conclusion, that a subsequent combined application of the mathematical and physical theory of radiation transfer might provide a series of quite interesting new data on the physical nature of planetary atmospheres.

*** THE END ***

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